IN WATERSHED PROTECTION

FROM

THE WESTERN RANGE—A GREAT BUT NEGLECTED NATURAL RESOURCE

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IN WATERSHED PROTECTION

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Preservation of satisfactory watershed conditions on range lands is vital to the well-being of the West and therefore is of concern to the entire Nation. Most towns and villages, many cities such as Los Angeles, Salt Lake City, and Denver, and innumerable ranches and farms rely on a usable and adequate supply of water produced wholly or in part on range-land watersheds. Irrigation enterprises representing investments of nearly 6 billion dollars depend on a stable soil mantle and stream flow from water-yielding ranges. Water power and recreation for multitudes of people are sustained in many cases by stream flow from range watersheds. A large population is dependent on the soil of range lands to produce forage upon which the 2-billion-dollar grazing industry and its source of income are based.

The range watershed situation presents three aspects: Eighty-five percent of the flow of important western streams comes from about 232 million acres, of which 79 percent is range lands. Silt is being borne down into these streams from erosion on approximately 352 million acres, practically all of which is grazed. Finally, much of the remainder of western range lands, such as those in the Great Basin and Great Plains, is eroding so seriously that it is imperiling productive capacity of the land, even though none of this eroded material is contributing to larger streams.

All this points clearly to the great importance of constantly maintaining an unbroken and productive soil mantle on all range land and the maximum yield of water from range watersheds; yet little thought has been given to the conservation of these values on other than the national forests and some municipally owned areas. Depletion of vegetation, as shown previously, has been the rule for the most part under other types of ownership or control, and with it have come floods and erosion menacing the social and economic security of the entire region. The destruction of soil and impairment of watershed values is without doubt one of the gravest results from misuse of the range.

Watersheds of the Virgin Range

The nature of the vegetation and soil mantle that clothed the watersheds of the virgin range, the normal course of stream flow, and the characteristics of natural erosion can be estimated from the testimony of present conditions on well-managed national forests and protected municipal watersheds, from such vestiges of primitive areas as have thus far escaped depletion, and to some extent from geologic evidence. Here may be seen how, during past centuries, soils were safeguarded against excessive erosion and leaching by the binding power of plant roots which filled the surface and subsurface layers and by the physical protection which the plant cover and

organic mulch provided. As rains fell on the area, the full impact was broken by the aerial parts of the vegetation, thereby preventing compacting of the soil surface. On the virgin range dead plants and herbage formed a ground litter, and eventually mixed year after year with the mineral soil and produced a loose, porous earth mantle which absorbed and retained against evaporation the maximum quantity of water from rain and melting snow. The channels formed by plant roots facilitated percolation. As the surface water ran off its velocity was reduced by plant and litter obstructions which checked and broke up the flow. Forest and shrub litter prevented direct access to the soil by water flowing off slopes, and a similar effect though not so complete in semiarid areas resulted from litter of herbaceous plants, hence run-off water was clear or almost so. The water absorbed by the topsoil percolated through the lower soil depths and rock crevices to issue forth later as springs. These maintain the flow of rivers and streams that have made possible irrigation agriculture, electricity for industry, and municipal water supplies.

In that stable and porous soil mantle the young nation pioneering its way into the West had a priceless resource of which it was then and for many decades thereafter unaware. It was a resource built up by the age-old process of soil building and normal erosion, which progresses with the slowness of geologic time, and has throughout millenniums sculptured and molded the face of the earth. The soil of the mountain slopes and the alluvium of the valley floors have been produced in this way—even the rocks of which most mountains are composed have been formed of sediments which are products of older periods of erosion and deposition. The principal method of transportation of the weathered material from the slopes was by natural gravity creep rather than by stripping and gullying by water—the creep of the soil being rarely rapid enough to disturb plant populations or modify their general aspect. Surface run-off carried a minimum of silt, destructive floods were unknown on many areas and uncommon on most others, and streams were generally clear, receiving what silt load they carried from the bottom of channels rather than from the vegetated slopes and protected stream banks.

Ordinarily erosion progressed so slowly that soil was formed or accumulated slightly more rapidly than it was removed. Only under unusual conditions, as in Bryce Canyon, Utah, on certain Mancos shale areas in Colorado and Utah, on the Chinle bad lands of Arizona, and in the Breaks of the Missouri River, have adverse climatic and geologic conditions prevented the fixing of the land surfaces by soil formation and plant growth. In these relatively few instances, run-off has been rapid and normal erosion pronounced, giving rise to muddy streams whose flow fluctuated greatly.

Elsewhere soil and vegetative cover were sustained by virtue of a delicate balance between the constructive and destructive forces. On the one hand the weathering of rock and plant succession built up the soil mantle, and the vegetation that blanketed it served to hold it in place; on the other hand, the destructive forces of a rigorous and variable climate and of steep slopes operated against this accumulation and stabilization. Vegetation was invariably the deciding factor in the balance. The presence of a natural plant cover enabled the constructive forces to hold sway and to preserve watershed values.

The Flood and Erosion Menace of Recent Years

When the white man's herds of cattle and sheep multiplied beyond the capacity of the range to carry them properly, depletion of vegetation upset this natural balance and the utility of the virgin watersheds became impaired. As overgrazing and fire reduced the density of the

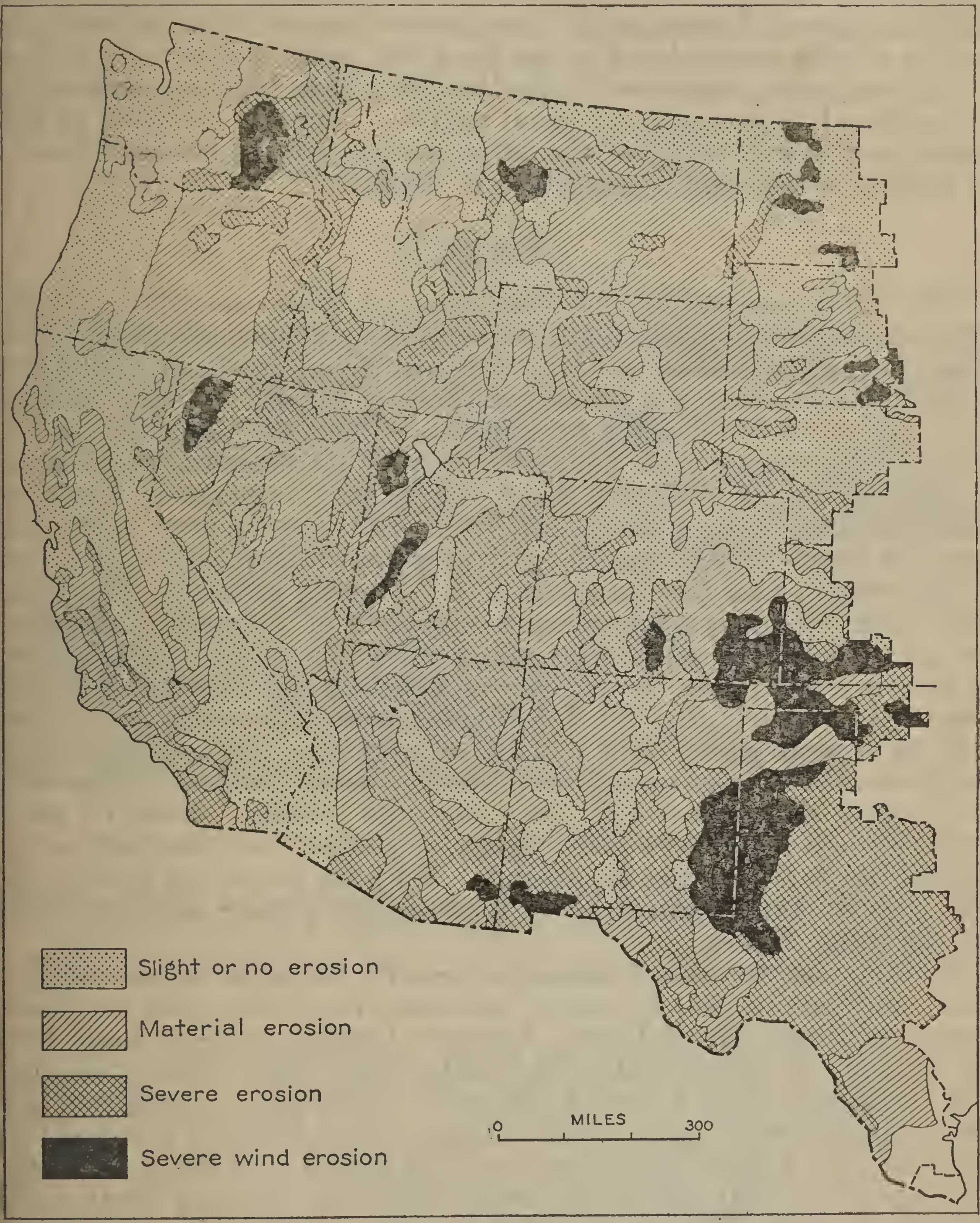

Figure 65.—CHARACTER AND EXTENT OF EROSION ON WESTERN RANGE LANDS.

As a result of range depletion, accelerated erosion is fast removing incredible quantities of soil from large areas, resulting in the devastation of range and agricultural lands and serious silting of irrigation improvements. In this process, the fertile topsoil on which the range depends is the first to go.

range cover, and as the litter and humus layers were broken through, the devastating forces of soil erosion were greatly accelerated (fig. 65) and unretarded run-off seriously modified the natural stream flow and caused many floods.

Over large areas of the western range the original fertile, spongelike soil cover has been gashed and stripped off, exposing a sterile, less pervious substratum. Deep gullies and gorgelike channels are common in the valleys and meadows, and slopes have been cut and carved until mere islands of fertile soil remain. Watersheds that formerly yielded only steady, quiet-flowing streams and rivers now produce devastating floods when rains come and a shrunken, inadequate flow at other times. Depletion of plant cover has not only reduced the utility of the unregulated range land but with it has come such a biologic upset to watershed lands that they have become a menace to agricultural, industrial, and social welfare. The full meaning of this threat to the well-being of the entire range country becomes clearer as the havoc wrought is examined in detail.

FLOODS

The flood menace in the West has no static quality. As the effects of depletion are brought into action by abnormalities of storm, floods increase year by year in frequency and intensity. Scarcely a day passes during the period of summer rainstorms that western newspapers of one locality or another do not carry accounts of destruction by water and mud-rock flows. To be sure, such catastrophes are very different from the great inundations that the easterner has learned to expect from protracted heavy rains and melting snow. High water, sometimes reaching flood proportions, is also common in the spring in many western streams. But summer flash floods resulting from a single brief intensified storm or so-called cloudburst may be equally destructive of life and property. A stream course may be dry one minute and the next filled to the brim by a rush of silt- and debris-laden water that within the hour will be utterly gone. Not a drop of rain may have fallen in the valley lowlands upon which such sudden floods debouch. The only warning to the victims may have been the constant threat of plant depletion on watersheds above them—a portent only too seldom revealing its full meaning in advance. Without doubt the flood problem is acute and is becoming of increasingly greater significance in all the range States.

For the past 40 years floods, of a severity to which boulder-strewn fields and valleys bear evidence, have been increasing over the entire length and breadth of Utah. Between Ogden and Salt Lake City 15 canyons in the Wasatch Mountain front have within the past few decades produced such floods—all originating on depleted, privately owned range lands representing a total of only a few hundred acres and but a small portion of each individual watershed. In 1923, and again in 1930, floods and mud-rock flows pouring forth from certain of these canyons exceeded anything which has occurred in that area for at least 20,000 years (*10*). Boulders weighing as much as 200 tons were carried into the valley, farm lands were ruined, homes and other improvements were destroyed, and lives were lost (fig. 66). In 1932 at least 27 important watersheds in the State flooded. An investigation of these areas by State and Federal agencies revealed that this serious situation has developed largely since settlement and that depleted range lands are the chief source of flood waters.

Several drainages in Colorado, tributary to the general area surrounding Denver, are highly susceptible to rapid run-off and periodically produce major floods. From a special examination of the watersheds, made in 1934 it was readily determined that, while the flood menace in this locality was already pronounced, still more serious flooding could be expected if depletion of vegetation continued. There is little doubt that the Pueblo floods of 1921 were due in part to depleted watersheds. They swept the entire Arkansas River Valley from Florence 30 miles west of Pueblo to the State line, causing tremendous waste of property and heavy loss of life.

FIGURE 66.—PROPERTY AND IMPROVEMENTS DEVASTATED BY MUD-ROCK FLOWS.

Sweeping out of the overgrazed watersheds in Davis County, Utah, mud-rock flows, carrying boulders weighing as much as 200 tons, devastated 1,800 acres of the most valuable garden, orchard, and farm land in the State, wrecked homes and farm buildings, and blocked or washed out highways and railroads. Such catastrophes are common in varying degrees of severity throughout the depleted range areas of the West.

Some of the most serious floods resulting from depletion of the plant cover of watersheds have occurred in California, and among these the Tehachapi flood of 1932 stands out as a glaring example of effect of misused range lands. In September 1932 the concentration of water from a heavy rain storm near Tehachapi Pass unleashed its fury on the valley lowlands and caused loss of life and property. The 1934 floods, caused by destruction of vegetation by fire on the watersheds near Los Angeles, attracted Nation-wide attention because of the damage caused. Sacramento Valley experienced a disastrous flood in 1928 as a result of rapid run-off from the exposed slopes of its catchment basins. These are examples of major floods. Other minor floods too numerous to mention, have occurred periodically over much of the interior basin and southern coastal region, building up a staggering total of losses.

In contrast to the spectacular mountain floods oftentimes accompanied by mud-rock flows, are the more common floods of silt-bearing water in the Southwest and Colorado Plateau. In these regions of more gentle gradients and sparsely-vegetated slopes, floods have always occurred, but historical evidence together with field investigation clearly indicate that they are yearly becoming more prevalent and more destructive.

In any presentation of the western flood problem it cannot too strongly be stressed that the communities desolated, the individuals bankrupt and bereaved by these floods have in many instances paid in life and property for the privileges enjoyed by themselves or others in the free use of watershed range. The evidence of this is clear. In the Escalante River Valley in southern Utah, for example, the first devastating floods occurred approximately 15 years after the settlers began to crowd the ranges with their herds. Since that time annual floods have been almost the rule, and in the single year of 1932, 19 major floods raged through portions of this valley, inundating agricultural land and tearing away sections of the fertile alluvial valley fill. In 1921, five drainages in western Colorado flooded during a storm that brought only 2.5 inches of precipitation over a 4-day period. The waters from one of the canyons washed out several miles of railroad track and those from another cut a new stream channel directly through the town of Lake City. Run-off from depleted range lands on the tributaries of the Virgin River in southern Utah swelled the river's flow sufficiently during the early spring of 1931 to take out bridges, inundate agricultural lands, and raise the flow of the Colorado River at Boulder Dam higher than had been anticipated for the whole of the Colorado River drainage.

The agricultural lands of the San Juan and Paria River Valleys in Utah have similarly been inundated and eroded, resulting in the abandonment of settlements. Historical evidence shows that the first serious flood came approximately 15 years after settlement, and that from then on catastrophes appeared with increasing frequency.

Further substantiation is given by Olmstead's (*96*) investigations in the Gila River Valley in Arizona where he found a remarkable difference between the destructive floods occurring during the first two decades of the present century and those of the early days. The earlier floods spread out over the countryside with relatively little destruction. The tearing out of great channels and depositing of sterile sands on fertile soil are entirely recent phenomena.

EROSION

ACCELERATED EROSION FOLLOWING RANGE ABUSE

To understand what erosion is doing to western watersheds today, it is essential to have clearly in mind what is meant by accelerated erosion, which followed misuse of land and forage, as distinguished from the normal erosion that has always been in operation. Accelerated erosion is a relatively rapid process, removing from the slopes and even flats soil that was ages in the making. Abnormal in action, it proceeds from man-made rather than natural causes. It is induced chiefly by the destruction of plant cover and the consequent disturbance of the natural balance so necessary to a stabilized soil surface. Accelerated erosion is of several types, the most important

being sheet, gully, and trench erosion caused by water, and another form of sheet erosion caused by wind. Gully and sheet erosion are most pronounced on steep mountainous slopes, trench erosion in the low gradient valleys characteristic of the Southwest, and wind erosion on flat desert or plains country. The seriousness of accelerated erosion is often not recognized until the eroded soil and other debris is deposited destructively on valley floors and along stream channels.

FIGURE 67.—MOUNTAIN SLOPES STRIPPED BARE.

When vegetation that has bound and protected the soil and retarded run-off on the mountain slopes is destroyed, the run-off washes away the soil itself which will require thousands of years to replace. Often a sterile rocky substratum is exposed, as in the above foreground. The vegetated islands of soil that remain as shown in the background of this view, will soon be eroded and gone unless the plant cover on the denuded slopes is restored.

On the mountain slopes, under sheet and gully erosion, soil removal can proceed at a terrific rate. Following the depletion of vegetation, water from heavy rains flows rapidly over the surface, transporting fine soil material with it. By this process a sheet of the fertile top soil has been removed from millions of acres of range land. Where soil texture and topography abet this action, the entire soil cover may be removed (fig. 67). In most situations, gullies also develop early and continue throughout the erosion cycle as the dominant process. In the early phases of gully formation, parallel stringers, often called "shoestring erosion", streak the eroding slopes and form a branched system of deep cuts and washes as they increase in size.

Trench erosion or arroyo cutting is most common in the Colorado Plateau and Southwestern regions, where alluvial-filled valleys are being deeply cut with a labyrinth of vertical-walled channels. Many such trenches, however, have also cut through valleys in Cali-

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fornia, Oregon, and elsewhere. Trench erosion arises usually from a break in the surface soils in which the run-off concentrates and channels rapidly through the valley flats. As the initial trench or arroyo advances by headward cutting, tributary trenches develop wherever lateral drainages are intersected and in turn grow into major cuts, each one excavating huge sections of the valley floor.

Wind erosion tears away and lifts in air the finer soil particles from the inadequately protected surface, at the same time that coarser particles are swept along the ground and oftentimes heaped into dunes. In some instances what is known as "desert pavement", consisting of residual rock fragments on the surface of the ground, characterizes the advance stages of this process.

Destruction caused by accelerated erosion on range lands, while costly in social and economic values everywhere, differs considerably in the different physiographic types in the western range areas. These types are, broadly, the mountain regions, the Colorado Plateau and the Southwest, the northern desert valleys, and the Great Plains.

EROSION IN THE MOUNTAIN REGIONS

Erosion and soil wastage present one of their most serious problems on the steeper grazing lands. From the mountains of the Pacific Coast to the eastern slopes of the Rockies, the utility of many overgrazed watersheds has diminished appreciably through the process of erosion. Slopes once comparatively uniform and smooth are marred with sharp niche-like gullies cut to subsoil or sterile bedrock. Mountain meadows have been drained and ruined following the development of gullies and channels in their deep mellow soil. Large areas have had part or all of the topsoil removed by sheet erosion—less striking than gully or trench erosion, but none the less serious. The full meaning of complete removal of the topsoil by sheet erosion under the dry climatic conditions of the West becomes very evident when it is realized that since the recession of ancient Lake Bonneville that occupied basins in the intermountain region 50,000 years ago, only 10 to 14 inches of humic soil has been formed on the most favorable sites of its old beaches and deltas.

What this situation amounts to on mismanaged mountain range in Utah was brought out by a special investigation of a seriously depleted watershed area in Davis County. Here overgrazing and fire had so stripped off the plant cover as to permit 18 to 36 inches of topsoil to be removed on approximately 21 percent of the area; 6 to 18 inches on 22 percent; up to 6 inches on 39 percent; and on only 18 percent of the area was the soil undisturbed. Badly depleted portions are ripped and torn by gullies 3 to 4 feet deep. Stream channels in this area have recently been scoured almost to their heads and in their lower reaches have been cut as much as 70 feet in depth and 200 or more feet wide.

In Idaho and Oregon the slopes of many drainage basins of the Owyhee River are badly eroded and streams which formerly flowed between grassy banks are now seeping along through sandy washes or flowing through raw cuts with steep, sloughing sides. On foothill tributaries of the Snake River in this same general region both sheet and gully erosion are also very evident. In California severe

gully and sheet erosion characterizes a large area of overgrazed land in coast drainage from Ventura County southward, and in the San Joaquin and Sacramento River basins. In other parts of this State erosion is present in varying degrees of seriousness, and is particularly evident on mountain meadows subject to concentrated grazing.

COLORADO PLATEAU AND SOUTHWESTERN REGIONS

Accelerated erosion on the Colorado Plateau and in the Southwest is in general similar to that in mountainous areas but distinctive in detail. In the depleted intermediate and lower elevational zones in these regions channeling and arroyo cutting of alluvium-filled valleys is virtually eating the heart out of the best grazing and agricultural lands (fig. 68). On depleted mesa lands the topsoil

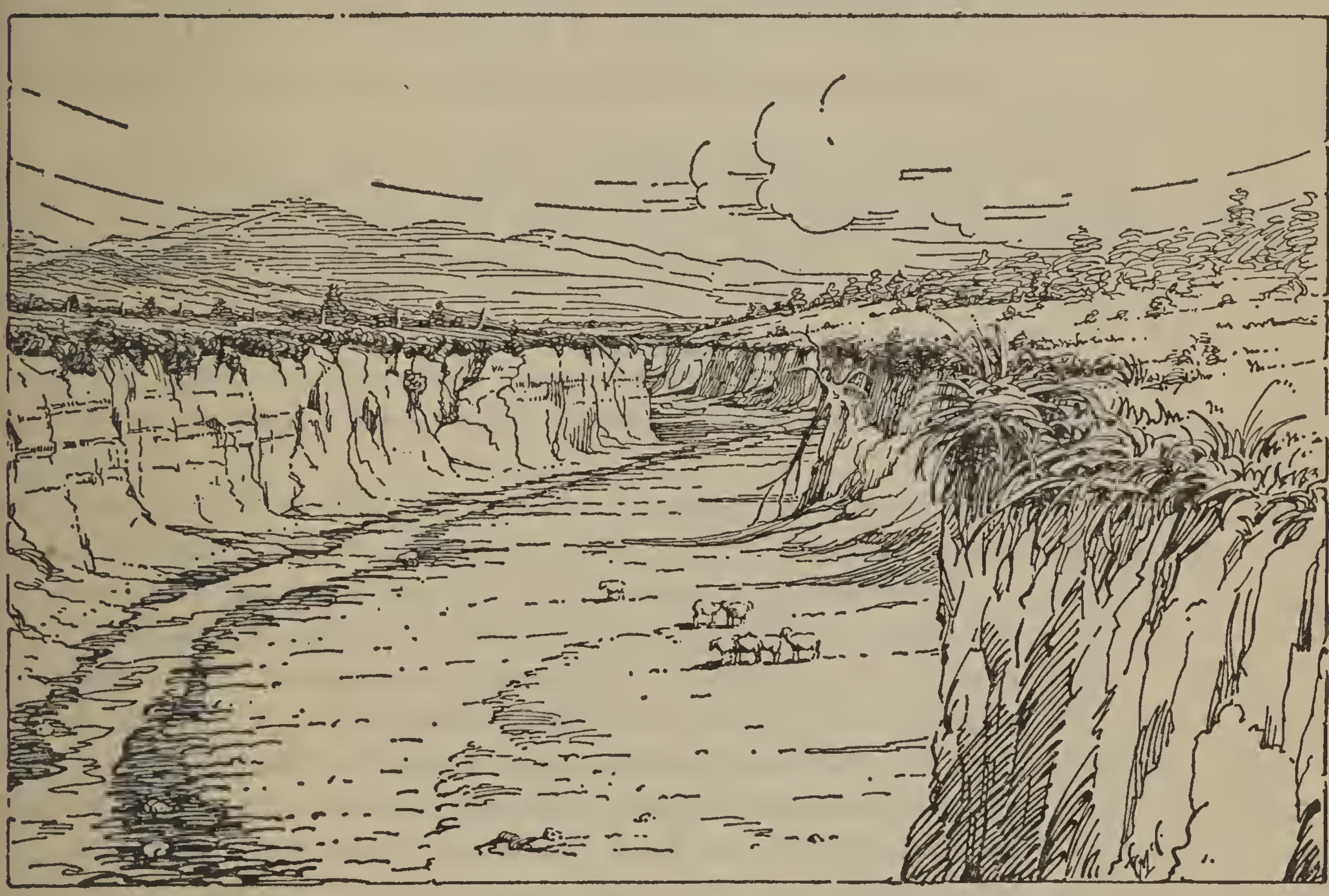

FIGURE 68.—FERTILE VALLEYS DEEPLY TRENCHED.

This view of upper Kanab Creek, Utah, illustrates the channel-cutting resulting from range depletion. Recent erosion has channeled thousands of tons of soil out of the valley floors. Trenches 20 to 100 feet deep and 200 to 500 feet wide are common where, prior to settlement, only shallow streams or drainage depressions existed. In this way, large tracts of fertile and productive land in the Southwest have been ruined.

has been blown or washed away in sheets, leaving accumulations of loose sand, gravel, and rock, or pedestal-like remnants of soil. In the higher elevational zones that have not escaped range deterioration, meadow lands are deeply channeled and drained of their former source of natural subirrigation.

The general acceleration of erosion on the Colorado River drainage basin north of the Grand Canyon was determined by a survey made in 1932 and 1933. Of 115 drainages examined upon which unregulated grazing had been permitted, 111 were eroding at a rate considerably more rapid than normal. In Wyoming and northern Utah raw gullies were frequent and active stream-bed channeling not uncommon. In Colorado and southern Utah the most serious type of erosion was the trenching or channeling of the loose, fertile soil

deposits of the productive valleys, of which Kanab Creek, Johnson Valley, and the Virgin and San Juan Rivers in southern Utah are typical.

Kanab Creek formerly flowed over the floor of a broad, fertile, well-vegetated valley. In the relatively brief period since range livestock were first introduced by the Mormon pioneers, its whole character has changed and it is now confined to a miniature "Grand Canyon" with a channel 30 to 100 feet deep and 200 or more feet wide. Johnson Valley, now called Johnson Wash because of the trenching of the previously aggraded valley floor, is cut with a many-branched arroyo which reaches a depth of 40 feet and a width of more than 300 feet, from which thousands of tons of soil have recently been removed. In the lower valley of the Virgin River heavy silt deposits swept by accelerated erosion from its upper reaches are so clogging the stream flow as to send it meandering over the valley floor, where it is removing additional surface soil and inundating agricultural lands.

In the Southwest abnormal erosion has caused some areas to resemble natural badlands. Portions of the Rio Puerco and Rio Salado Valleys in New Mexico, and the San Simon and San Pedro Valleys in Arizona have been carved with deep channels which divide the valley floor into innumerable isolated segments. In the valley of the Rio Puerco, where only small channels existed prior to 1885, destructive erosion has cut trenches 200 to 500 feet wide in the fertile soil of its floor.

A survey of the upper Rio Grande drainage in New Mexico above Elephant Butte Dam found accelerated erosion within all of nine vegetative types. Within this area only 25 percent of the watershed is in fair to good condition, 35 percent is characterized by advanced erosion, and 40 percent by excessive erosion. The watersheds of the Rio Grande tributaries below Embudo, N. Mex., have a badly depleted cover of range vegetation and discharge enormous quantities of silt and floodwater into the main channel. This silt, carried down and deposited in the low-gradient channel of the Middle Valley, has so built up the channel as to slow down the flow of the river, causing the water-logging of 80,000 acres of formerly productive farm land.

Other studies by the Southwestern Forest and Range Experiment Station, on the Salt River watershed in Arizona, show that an average of 432 cubic feet per acre of topsoil and soil-forming materials is lost annually from typical deteriorated brush ranges.

On mesa areas, such as those on the Navajo Indian Reservation, great sheets of surface soil from the grassland have been blown or washed away as a direct result of grazing abuse, and arroyos 30 to 50 feet wide and 10 to 20 feet deep, with tributary gullies 8 feet wide and 5 feet deep, are common where originally only shallow streambeds and depressions were present.

The higher plateau grazing areas which have been used with no regard to watershed values have been severely channeled. The lower Rio Jemez drainage is a typical example. Here arroyos have been cut through at least 25 percent of the meadows, and 40 to 50 percent more are in the process of cutting.

NORTHERN DESERT VALLEY REGIONS

The erosion picture presented by northern desert valley lands, chiefly of the Great Basin region in Nevada and Utah, is distinctive. In these valleys, although the heavy rainstorms of summer are often of sufficient intensity to cause trouble, the chief erosive agent is wind. Over large areas much of the topsoil has been blown away, and clumps of grass and shrubs, whose roots hold small hummocks of soil together, mark the scattered spots where overgrazing has failed to kill the plant cover. New sand dunes forming in these valleys present a serious threat. One particularly badly overgrazed area near Grantsville, Utah, has been the source of severe dust storms which have blanketed Salt Lake City and Ogden. "Blow-out" holes, 12 feet deep and 4 to 6 acres in extent, have been formed and the surface soil has been stripped or shifted over an area of more than 35,000 acres.[37]

The lowland areas of the Columbia River Basin in Idaho, Oregon, and Washington are suffering also from wind erosion, and sand dunes have formed in many localities. As some of these lands receive more precipitation than do the Utah and Nevada lowlands, they are more generally eroded by water.

GREAT PLAINS

The erosion on range lands of the Great Plains contributes a considerable portion of the great silt load carried by the Missouri, Platte, Arkansas, Red, and other rivers, with their tributaries. Even in the Badlands of Montana and the Dakotas, plant-cover depletion is accelerating erosion greatly beyond its normal rapid rate. Gully erosion is less widespread and less serious, however, than sheet erosion because of soil, topographic, and climatic conditions.

Dust storms, as a manifestation of sheet erosion, have become increasingly more frequent and serious in the Plains region. Thousands of acres of true grazing land from the Dakotas south to Texas, upon which the sod had been broken for agricultural purposes, are the main source of these storms. Areas suffering merely from overgrazing have contributed somewhat toward the dust supply, but their role is overshadowed by the dust resulting from the injudicious attempt to cultivate land unfit for that purpose. Several localities, generally smaller than the famous "dust bowl" of eastern Colorado and western Kansas, are devastated and have in turn ruined many acres of adjacent lands.

The examples of erosion and flood damage specifically cited might be multiplied indefinitely. However, the illustrations presented show that the curse of floods and erosion that has developed over the West in the last half century is a serious and rapidly increasing menace. Floods of accelerating frequency and severity, and slopes and valleys riddled with gullies and chasms bear convincing testimony to man's misuse of the range resources.

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[37] According to unpublished data of the Soil Conservation Service prepared by G. S. Quate and H. J. Helm in 1935.

Causes of Accelerated Erosion and Floods

That the present serious problem of floods and erosion on the western watersheds is the result of past misuse of range lands is substantiated by extensive evidence of the part played by various contributing factors. Of these the most prominent are the physical factors of climate, soil, and topography and the biological factors of vegetation and organic matter in and on the soil.

CLIMATE

Climate exerts its influence directly on erosion and floods through the amount, kind, and intensity of precipitation and indirectly through its effect on vegetation and soil. Even this direct effect has many ramifications, however, when it is considered that although the West is essentially arid, and some areas in the lower deserts receive as little as 3 to 4 inches of rainfall annually, other areas in the higher mountains receive as much as 60 inches. The kind and intensity of precipitation vary greatly also. At the lower elevations precipitation falls largely as rain, and in many places in storms of sufficiently great intensity to result in rapid accumulations of water having great erosive force. Because of the naturally scant protective cover of vegetation in the arid and semiarid portions, rains relatively light in character as compared to those in more humid areas may run off so readily and develop into such violent floods that they are classed as torrential. In the mountain areas a large proportion of the annual fall comes as snow, which is released as free water only during the spring and early summer. Rains that fall on steep mountain slopes may be intense, greatly increasing the danger of erosion on any soil not bound in place or otherwise inadequately protected by plants; or they may be moderate, causing severe erosion only where plant depletion is most serious and topography steepest.

Hard rains falling on denuded land, whether in the desert regions or in the mountains, result in rapid accumulations of water that inevitably cause the gullying of slopes and trenching of valleys. If there are depleted range areas in the West today on which erosion is only slight or moderate, it is principally because rainfall there is uniformly low in intensity, slope is negligible, or the soil is unusually porous.

The indirect relation of climate to accelerated erosion and floods is exerted through the effect of drought, high temperature, wind, and high rates of evaporation on vegetation and soil. Undoubtedly drought, particularly protracted drought, has contributed greatly to the decline of the watershed value of certain areas by killing off some of the plants or limiting their growth and reducing their density. The death or diminished growth of the plant means, in turn, a general depletion of the plant cover and less physical protection to the soil. During droughts, the physical properties of the soil are modified by excessive drying, its power of cohesion is lessened, and it becomes more susceptible to the forces of wind and water. The stage is thus set for destructive erosion.

High temperatures and winds, causing excessive evaporation, act on the plants and soil in exactly the same manner as drought. Regardless of how much precipitation occurs, it is of no value as a source of water for plants or for stream flow if it evaporates almost as rapidly as it falls. These various forms of the action of climate on the soil and vegetation mantle are serious enough when soil and topography also favor erosion and flooding, but their effects are most pronounced when the plant cover has been depleted by overgrazing and fire.

SOILS

The inherent nature of the soil plays an important role in determining the rate of erosion and the percent of the total precipitation which runs off the surface of any area. Some soils, deficient in plant nutrients, are capable of supporting only a sparse cover of vegetation which influences their absorptive powers but little and affords them a minimum of physical protection against erosion. The relative erosibility of different soils is greatly influenced by such physical properties as their imperviousness to water and their water-holding capacity. The Mancos shales of certain parts of the West, for example, produce soils that are highly impervious, permitting rapid run-off of a large part of the precipitation and a consequent rapid natural erosion. In contrast, soils from the Wasatch conglomerate naturally absorb water readily, permit less run-off, and consequently are not easily eroded. All soils, however, regardless of their inherent nature and the parent rock from which they are derived, absorb precipitation most readily and are subject to a minimum of erosion when they are well clothed with vegetation.

TOPOGRAPHY

Topography of a watershed is a significant factor in determining the extent of erosion and character of run-off. Steepness of slope naturally influences velocity of run-off; and since the transporting power of water increases as the fourth to sixth power of its velocity, it is evident that soil movement would be greater on steeper slopes, other factors being equal. This in turn increases its cutting power. Increased velocity means also that the flowing water passes over the surface more rapidly, thus allowing less time for absorption and penetration. Gravity creep of certain soils on steep slopes, independent of the influence of water, is noticeable in some instances, indicating that the natural balance which is so necessary to soil stability hangs very precariously.

The topographic influence expresses itself also in its modification of the action of general and local climate. Rugged, broken country is less likely to suffer wind erosion than flat or rolling areas where winds can be generated and blow unobstructed with great force. The action of high temperatures and evaporation vary with exposure to the sun's rays, as is evident in the contrast between plant cover and soil mantle on the north and south slopes of canyons and mountains.

Nearly all the effects of topography, however, as in the case of climate or soil, are greatly modified by the plant growth. Under any but extreme conditions of climate, soil, and topography this vegetation mantle is the critical factor of the watershed. Even on slopes steeper than the angle of repose, soils are built up under it. Furthermore, vegetation is the one factor that man can control. Thus the major interest in analyzing the causes of accelerated run-off and erosion centers on the part played by the plant cover.

VEGETATION

On the nonforested arid and semiarid range lands of the West herbaceous and shrubby plants form the vegetation which furnishes protection to the watersheds. Even on forest lands, and especially those open forest types which are suitable for grazing, the herbaceous and shrubby plant growth materially supplements the value of the timber growth and its litter in affording adequate watershed protection. This is especially true in the open orchard-like stands of the piñon-juniper type, where only a small proportion of the soil is directly protected by tree growth. As in forests (*8*, *86*), it is not the areal growth alone which is of value. The total plant cover, the root system, the litter, and the humic horizon of the upper layers of the soil composed chiefly of decaying organic matter, all make up the range cover of value in the protection of watersheds. In the main, the vegetation present under virgin conditions represents the type developed by natural forces best adapted to the specific climatic, soil, and other conditions of the particular site.

It has been rather generally recognized for a number of years that the protective cover on range lands has a marked effect in controlling soil erosion and abnormal run-off. Where overgrazing and fire have been rampant, serious consequences were observed; and where some degree of protection has been afforded, favorable watershed conditions have prevailed. Restoration of the plant cover on denuded areas has indicated also its beneficial effect. For example, Manti canyon in Utah (*108*), which was overgrazed badly beginning in the late 70's, produced a number of serious floods between 1888 and 1902. In 1903 this area was included within the Manti National Forest and, after 5 years of complete protection followed by regulated grazing, the range cover has been greatly improved, accelerated erosion halted, and all flooding of any consequence stopped.

The general outcome of the many observations on the relation of range cover to conservation of the watershed resource was, however, one of confusion, as shown by the differences in concepts held by some geologists, engineers, ecologists, and foresters. It became apparent that the role of vegetation had to be ascertained quantitatively by detailed investigation. Research on this subject was accordingly undertaken and, though a vast amount of detailed work still remains to be done, certain general concepts have already been developed and proved.

EFFECT OF DENSITY OF VEGETATION

The first of these investigations (*51*) of any consequence on western range land was instituted by the Forest Service on the Wasatch Plateau, near Ephraim, Utah, in 1912, where a study was made of the run-off and erosion from two grazing areas of about 10 acres each, fairly similar except for the cover of vegetation. Area A had an original plant density of 16 percent and Area B a density of 40 percent. Both areas were grazed and for the 6 years, 1915 to 1920, the cover was maintained at the original densities. During the period 1921 to 1923 Area A was allowed to revegetate until its density approximately equaled that of Area B. From 1924 to 1929 both areas were grazed and maintained at equal densities. The results from summer rains are given in table 55.

TABLE 55.—*The influence of vegetation change on run-off percent and sediment removed during summer precipitation period from two test areas on the Wasatch Plateau*

Values per acre for watershed A			Values per acre for watershed B			A/B ratios	
Plant density [1]	Surface run-off [2]	Sediment	Plant density [1]	Surface run-off [2]	Sediment	Run-off percent [2]	Sediment
Percent	*Percent*	*Cubic feet*	*Percent*	*Percent*	*Cubic feet*	*Ratio*	*Ratio*
16	10.33	133.8	40	2.52	24.7	4.10	5.42
16 to 40	8.74	105.0	40	3.03	37.3	2.88	2.82
40	5.49	19.2	40	5.23	7.7	1.05	2.48

[1] Plant density as here used is the percentage of total soil that is covered by the total spread of the plant growth.
[2] Percentages are based on effective precipitation.

With area A in a depleted condition the run-off percent and sediment removed were approximately 4.1 and 5.4 times that from area B. As the plant cover was gradually restored on the former, these differences diminished until the ratios for run-off percent and sediment were only 2.9 and 2.8. Finally, when the densities of the plant cover were made comparable, the run-off percent from the two areas was practically the same, and the excess of silt removed from A was reduced from 109.1 to 11.5 cubic feet.

This reduction of silt removed from area A following revegetation has far greater significance than merely the reduction of soil movement, because of its indirect effect on the future rate of absorption and percolation of the soil. This is shown by studies (*86*) conducted by the California Forest and Range Experiment Station, in which slightly less than 2 percent of sediment was introduced into clear water and allowed to percolate through a soil surface. It was found that the rate of percolation of this muddy water amounted to a reduction of 90 percent within 6 hours over the percolation rate for clear water. The sealing of soil pores by sedimentation not only immediately reduced the speed of percolation but this change remained permanent since the subsequent use of clear water did not restore the original percolation rate. This indicates clearly that

silt-laden water from eroding land tends to increase run-off by decreasing absorption on all areas over which it passes.

In southern California, where water is extremely valuable, it is desirable to save as much of the streamflow from mountain canyons as possible. The construction of storage basins is costly and there is a great dearth of suitable sites. A common practice, therefore, is to divert the clear water emerging from such canyons over the gravel beds at their mouths. The water is later pumped from the natural underground storage basins for domestic use and irrigation. If, however, the streamflow is muddy the gravels are quickly sealed by the silt and the water runs off to the ocean, resulting in a scarcity of the underground supply. It is vital, therefore, to prevent erosion of the watersheds which would produce muddy streamflow.

EFFECT OF DIFFERENT STAGES OF DEPLETION

Studies conducted on the Boise River watershed in Idaho, with the aid of a portable apparatus simulating natural rainfall, have demonstrated the value of different plant types in preventing erosion and conserving water on the granitic soils of that region. The effects of varying intensities of rainfall, degree of slope, and disturbance of soil were determined on comparable plots within four plant types ranging from the annual weed, which represents the most depleted type, to the bunchgrass, the most valuable. Under all conditions of the experiment the average percentage of rainfall which ran off and the amount of material eroded for the different types is as shown in figure 69.

The bunchgrass type, which has the greatest forage value of any local range type, and to which most grazing land in this area will ultimately revert if unabused, yielded very little run-off and silt. The downy chess and needlegrass-lupine types, which have succeeded the bunchgrass on overgrazed ranges at the lower and higher elevations, respectively, are distinctly less effective watershed covers. The manner in which these two types contribute to rapid run-off and erosion is shown by the fact that, on the average, 25.5 percent of the precipitation on the downy-chess cover and 47.6 percent on the needlegrass-lupine cover were unabsorbed. Further, as this water ran off it carried the equivalent of 2,017 and 4,783 pounds of soil per acre from the respective types. The annual-weed type affords far less protection than any of the others, permitting a 60.8 percent run-off which transported an equivalent of 15,280 pounds of soil per acre.

The characteristic root systems of the plants in the various types studied, as sketched in figure 69, indicate that for this investigation a dense mat of fine roots near the surface of the soil served best in protecting the soil from accelerated erosion and in obtaining maximum absorption.

The contribution of percent of slope, disturbed soil, and intensity of rainfall to these results is shown in table 56, which is a further

break-down of figure 69. A change in percent of slope was materially noticeable in modifying run-off in the downy chess type only, where excessive loss of water occurred on slopes greater than 30 percent. The unexpected decrease in the run-off from the steeper slope in the needlegrass-lupine type is attributed to the coarser texture of the soil on these slopes. Erosion was accelerated, however, by steeper slopes in every type except the bunchgrass. Disturbed soil as compared to undisturbed gave much the same effect as increased percent of slope. In this case decreased run-off following disturbance of the soil in the needlegrass-lupine type is due to the increase of absorption caused by loosening of the surface. High rainfall intensity accelerated both run-off and erosion from all types except the bunchgrass, which continued to afford suitable protection to the soil even when the intensity of the rainfall was doubled.

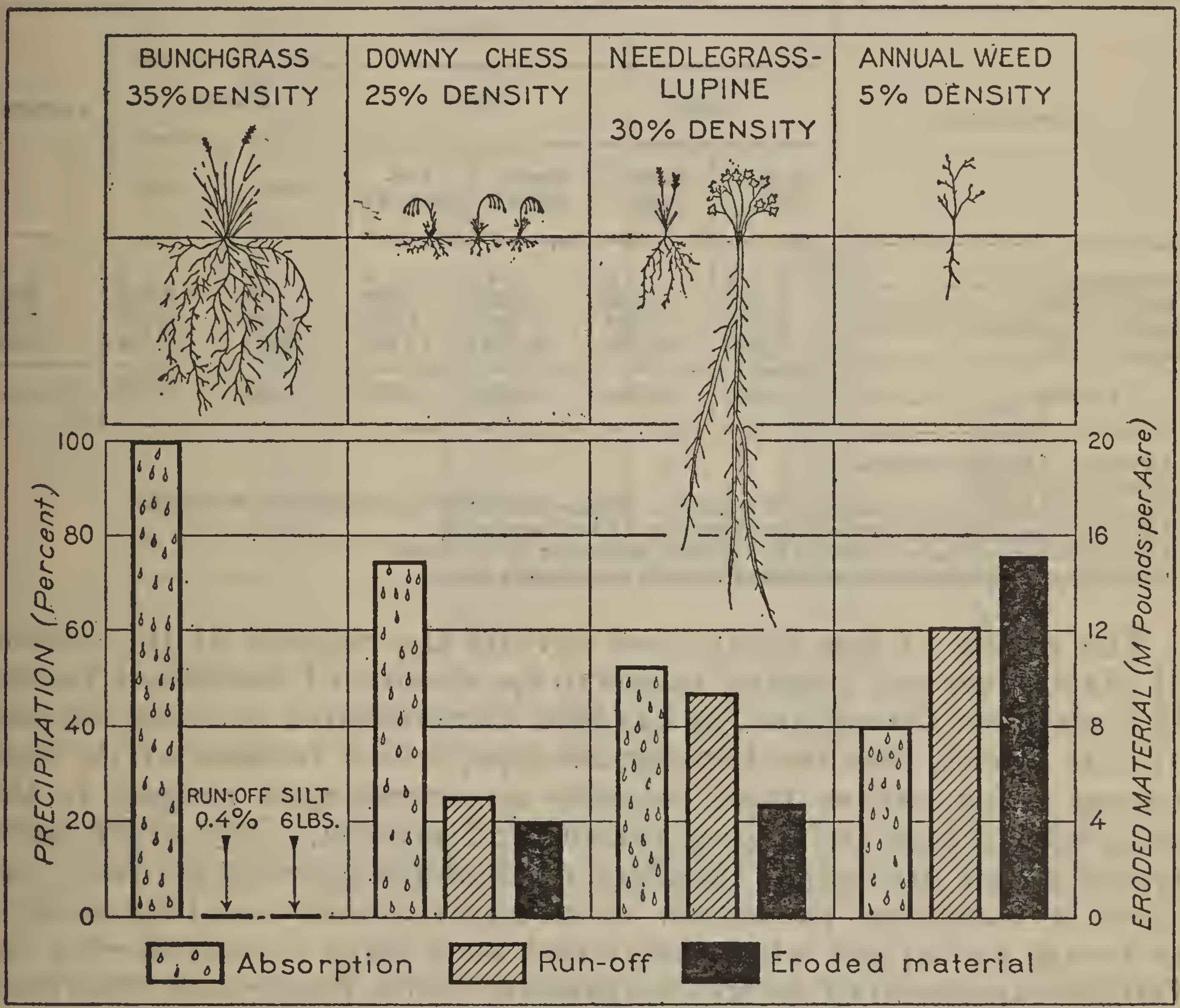

FIGURE 69.—THE MOST DESIRABLE FORAGE PLANTS ARE COMMONLY THE BEST WATERSHED PROTECTORS.

Run-off and erosion from rainfall are negligible where the bunchgrasses predominate—the highly palatable virgin-range cover characteristic of south-central Idaho. Both run-off and erosion are very pronounced where other plants have succeeded bunchgrass because of overgrazing. The greatest percent of run-off and the largest amount of eroded material come from annual weed cover—a plant cover which is an infallible expression of over utilization. A many-branched, fibrous root system is an important factor in retarding soil removal and aiding absorption.

TABLE 56.—*Run-off and amount of erosion (induced by artificial storms of 1.80 inches on four range types on the Boise River watershed) as influenced by steepness of slope, conditon of soil, and rate of rainfall*

Cover type	Run-off [1]						
	Slope		Soil		Rainfall [3]		Average [4]
	30 percent	40 percent	Undisturbed	Disturbed [5]	Low	High	
Bunchgrass	0.5	0.3	0.5	0.3	0.4	0.4	0.4
Downy chess	12.2	38.7	23.4	27.6	16.5	34.5	25.5
Needlegrass-lupine	55.6	44.3	49.7	40.1	41.6	54.5	47.6
Annual weeds	56.0	65.6	58.2	63.4	57.2	64.4	60.8
Average [6]	40.0	37.2	32.8	32.8	28.8	38.4	

Cover type	Erosion [2]						
	Slope		Soil		Rainfall		Average [4]
	30 percent	40 percent	Undisturbed	Disturbed [5]	Low	High	
Bunchgrass	6	6	6	6	6	6	6
Downy chess	395	3,640	939	3,095	578	3,456	2,017
Needlegrass-lupine	4,660	4,874	3,359	6,320	2,960	6,573	4,791
Annual weeds	4,790	25,770	12,006	18,554	12,976	17,584	15,280
Average [6]	2,508	8,573	4,078	6,994	4,139	6,905	

[1] Percent of rainfall applied.
[2] Pounds per acre.
[3] Low=0.03 inches per minute for 60 minutes. High=0.06 inches per minute for 30 minutes.
[4] Each figure represents the average of tests on 12 5-milacre plots.
[5] Artificial disturbance of surface to simulate trampling by livestock.
[6] Each figure represents the average of tests on 24 5-milacre plots.

The results of this study show vividly the relation of the decline of plant cover and grazing values to the decline of watershed values. It is observed throughout, as has been demonstrated in other sections of this report, that the bunchgrass type, which because of its high forage value suffers most severely on unmanaged ranges, is the most effective in stabilizing run-off and erosion. The other three types, which are actual invaders of depleted bunchgrass land, decline in watershed protection value approximately as they decline in forage value; and when the annual weed stage is reached—the infallible expression of severe overgrazing—both forage and watershed values have been reduced to the lowest point attainable under a plant cover.

EFFECT OF DEPLETION ON ABSORPTION

That vegetation has a definite and very important part in conserving precipitation on watersheds was substantiated by further studies in the same general area. Measurements were taken of the rate of absorption and percolation of surface water on paired plots, each 1 foot square. One of the pair supported a single herbaceous plant and the other was bare soil occurring between plants. Twenty-three pairs were compared for plants typical of well-managed ranges

and 16 pairs for plants common on depleted ranges. The results are shown in figure 70. That plots supporting desirable forage plants absorb water more rapidly than contiguous bare plots or even than plots supporting the less desirable plants, is readily understandable. It is interesting to note, however, that bare-soil spots on well-managed range were more absorbent than the bare places on depleted range, owing to the better soil conditions induced by the surrounding vegetation and its wider spreading root systems. Equal quantities of water applied on these plots penetrated approximately 5 inches on vegetated plots on managed range as compared to 3½ inches on vegetated plots on depleted range.

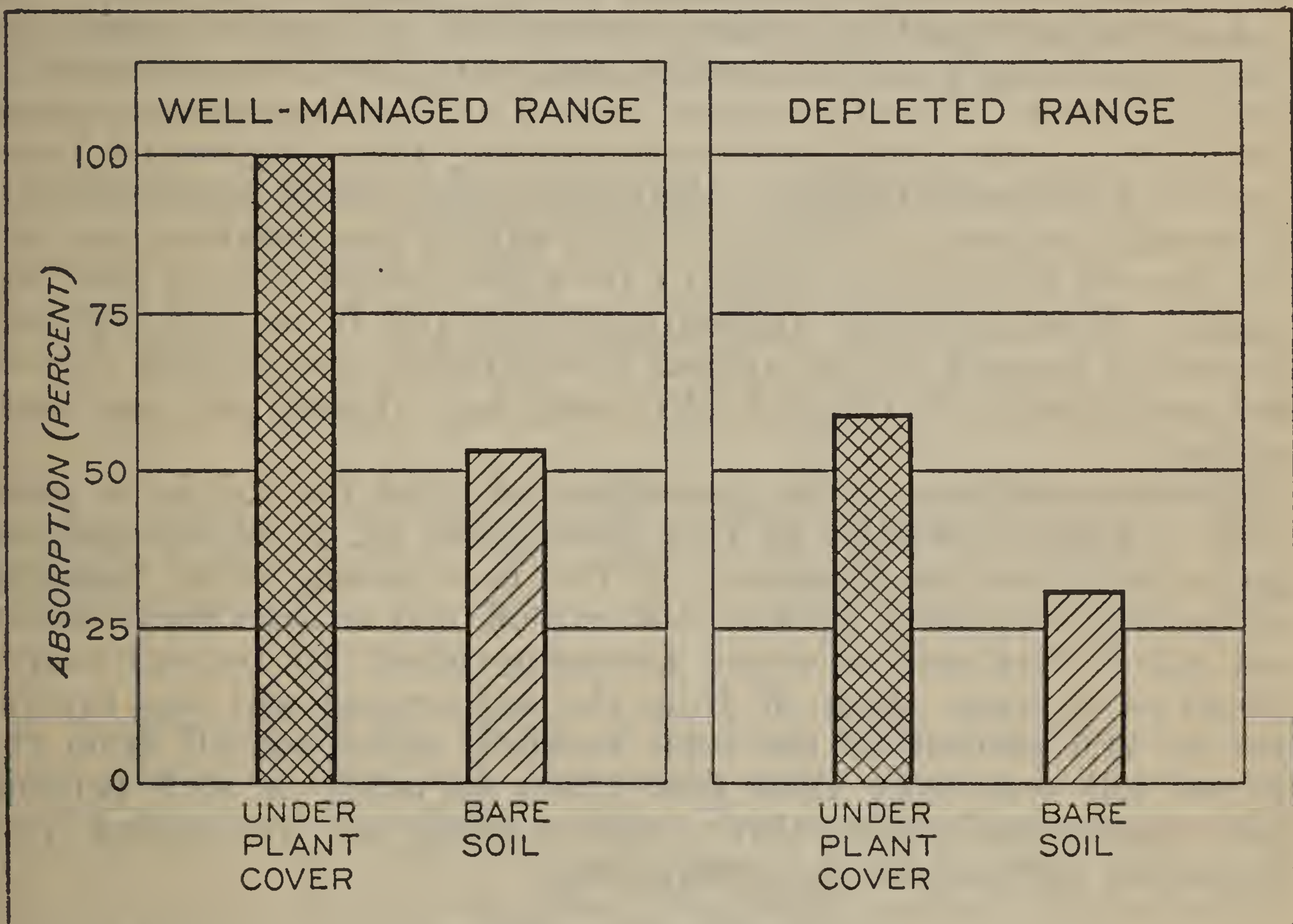

FIGURE 70.—THE EFFECT OF DEPLETION ON ABSORPTION.

Where plants are present, the rate of absorption of water by the soil is materially increased over that on bare soil. It is significant also that bare soil on well-managed range land absorbs water more rapidly than similar spots on overgrazed range. The data shown here are taken from averages obtained on plots on the Boise River watershed. Absorption under plant cover on well-managed range was at the rate of 0.44 inches per hour.

In every case the course of percolation appeared to follow plant roots, demonstrating the superiority of extensive and fibrous roots, characteristic of the perennial plants found on well-managed ranges, over the more poorly developed root systems of plants typical of depleted cover.

The necessity of maintaining an unbroken range cover, as demonstrated on the Boise River watershed, was further substantiated by a general survey of the area made by the Forest Service. This survey brought out the necessity for a plant-cover density of at least 30 percent to avoid erosion, since if grazing depletes the cover below that point, run-off and erosion will be accelerated and the utility of the watershed will be reduced.

SOUTHWESTERN STUDIES CONFIRM RESULTS

A distinct correlation between the extent of range depletion and degree of erosion was revealed in an investigation of range cover and accelerated erosion on the upper Rio Grande watershed by the Southwestern Forest and Range Experiment Station, in which erosion was classified as moderate, advanced, and excessive. It was found that range lands supporting a vegetation cover which had deteriorated 7 to 40 percent in reference to virgin conditions was eroding moderately; lands with a cover depleted 29 to 57 percent were in an advanced state of erosion; and where the cover had deteriorated 52 to 74 percent lands were eroding excessively.

An even more definite correlation between soil erosion and grass cover was brought out in further studies by the Forest Service in the Southwest. Here the annual run-off and soil erosion was measured from a grass range cover representing three degrees of depletion on a 25-percent slope. With the range cover approximately 25 percent depleted, 22 percent of the annual precipitation was surface run-off and the equivalent of 109 cubic feet of soil per acre was eroded. With the cover approximately 50 and 75 percent depleted, 28 and 32 percent of the annual precipitation was surface run-off and equivalents of 174 and 240 cubic feet of soil per acre were eroded.

Further emphasis on the protection afforded the soil by a plant cover is given in studies by F. L. Duley and M. F. Miller (*44*) on agricultural land in Missouri. In this case, among other things, a comparison was made between the run-off and erosion from barren and sod-covered soil on slopes averaging about 3.7 percent over a period of 6 years. Run-off from the sod-covered soil was equivalent to 11.6 percent of the total rainfall, while run-off from the barren soil was more than four times as much or 48.9 percent. One hundred and twenty-three times as much soil was eroded from the barren as from the sod-covered soil.

GEOLOGIC EVIDENCE

Geologic evidence obtained on the Davis County, Utah (*10*) and on certain Colorado River watersheds (*9*) has shown that the devastation of plant cover has been the major cause of accelerated erosion and uncontrolled run-off on these areas. Recent channel cutting and erosion has definitely exceeded any which has taken place for the last 20,000 years in Davis County, illustrating the unprecedented nature of the recent activity, at least in modern geologic times. Since the deterioration of plant cover is the only marked change in the factors effecting erosion and stream flow which occurred since settlement, it is logical to ascribe the activity to that source. On the Colorado River geologic evidence of the influence of plant cover was determined by investigating the gradational process of erosion on natural barren areas in which no acceleration was found. At the same time, on the surrounding localities once stabilized by a plant cover, erosion was accelerating. The deduction was clear that vegetative depletion was the major factor causing the present channeling and gullying on the formerly productive lands in this drainage.

DESTRUCTION OF VEGETATION BY FIRE GIVES COMPARABLE RESULTS

Depletion of vegetation by fire is of interest, since the results in erosion and floods are similar to those from persistent overgrazing. The La Crescenta flood in California is a dramatic illustration. On New Year's Day, 1934, a general rain fell over the southern California foothills including a 5,000 acre area that had been severely burned 2 months previously. As presented in table 57, the records of the California Forest and Range Experiment Station show that the burned Verdugo and Pickens drainages received approximately the same rainfall as the unburned areas to which they are compared and yet the erosion and run-off on them was tremendously greater. The most striking example was Pickens Canyon, where run-off was increased fortyfold and erosion approximately one thousandfold.

TABLE 57.—*Erosion and run-off from the La Crescenta flood area and on comparable unburned slopes*

Watershed	Rainfall	Area	Watershed affected		Peak run-off	Eroded material
			Burned	Unburned		
	Inches	*Square miles*	*Percent*	*Percent*	*Cubic feet per second*	*Cubic yards per square miles*
Burned Verdugo	12.5	19.30	33	67	320	30,700
Unburned San Dimas	10.8	16.85		100	53	56
Burned Pickens	12.5	.48	100		1,000	50,000
Unburned Fern and Bell	12.4	.30		100	25	52

A comparison of the effects of burning litter from small plots under controlled conditions was made under varying intensities of rainfall on typical California soils. The results substantiate other experiments in the destruction of organic cover in that superficial run-off was 3 to 16 times as great from bared as from litter-covered soil and erosion was about 1,200 times as great.

NET EFFECT ON STREAM FLOW

The results reported above are of great importance on all range lands throughout the West which deliver water for irrigation, power, or domestic use. Most of the usable stream flow comes from the melting of snow and from the gradual delivery from springs and seeps of snow water absorbed by the soil and broken-rock blanket of the watersheds. The more porous the soil cover the more percolation there is and the greater the value of this underground supply. It is the cover of vegetation, its litter, and related values which maintain maximum percolation. With removal of the vegetation the soil pores are quickly sealed and percolation is greatly reduced, as previously explained. Studies on the Wasatch Plateau in Utah have shown that the soil is saturated in the spring from having absorbed its maximum capacity. Spring surface run-off of melting snow was found to be practically unaffected by differences in the vegetation cover. On the experimental areas this spring run-off amounted to about 95 percent of the yearly water delivery by surface run-off.

The stream flow from the melting snow and underground water supply is generally clear, except as it may pick up sediment which had previously accumulated in the stream channel or as it may cut the sides of eroding channels.

On the other hand, in most of the range area summer rains furnish little of the yearly usable stream flow, yet they are the ones which cause most of the destructive floods. The soil eroded from slopes by summer rains is usually deposited in stream channels to clog them and to be carried further downstream by subsequent floods or high-water stages.

Restoration of the range cover on watersheds will result in a material reduction in surface run-off from summer rains and therefore a slight reduction in total yearly surface run-off, but this will be far more than offset by the control of erosion and flash floods with all of the destruction that they imply.

Notwithstanding, attempts are occasionally made to justify such great increases in summer rainfall run-off from depleted areas as have been shown in the studies cited. The theory is advanced that denuded watersheds yield a greater volume of stream flow than watersheds clothed with water-using vegetation, and, therefore, that destruction of the plant cover is no loss. The fallacy in such a theory is apparent when the test of common sense is applied. If true, then the ideal water-yielding watershed would approximate the water-shedding ability of a tin roof. What water fell on its nonabsorbent surface would immediately and completely run off; after the storm had passed, its slopes and gutters would be even drier than the stream beds fed by a denuded mountainside. But there is one great difference—one particular in which the watershed can never attain the ideal "tin-roof" condition. Assume that to overcome the undesirability of loss of rain water from the roof a barrel is placed beneath the eaves, just as a storage reservoir may be built in a canyon. One would say that it is only necessary to find a big enough barrel or to build a big enough reservoir to catch and hold all the water that falls. But here the "tin-roof" analogy breaks down, for the tin roof does not erode. How long would the effective life of the barrel be if each storm brought down from the roof great quantities of silt, mud, and debris such as is inevitably produced from a devegetated watershed? The barrel is soon filled and the precious moisture pours over its sides and is lost.

But, argues the theorist, much of this run-off will soak into the soil and be conserved in that way—an argument that overlooks the tests already cited, in which it has been shown how naturally porous and water-absorbing soil surfaces are clogged and rendered impervious by the fine silt washed over them. No experiments have as yet given any indication that the water loss represented by water use, transpiration, and evaporation by and from the plant cover of a mountain slope is at all comparable with the water loss and soil wastage from that same slope devegetated.

The only safe procedure is to maintain as effective a plant cover as possible on all important watersheds. Further research is required to determine the degree to which cover may be modified and still function satisfactorily in retarded run-off, in soil building and binding, in percolation of water, and in other ways to control erosion and stream flow.

OWNERSHIP OR CONTROL OF LAND AS A CONTRIBUTING FACTOR IN ACCELERATING RUN-OFF AND EROSION

Ownership or control of range-land watersheds has been a major factor contributing to their present impaired watershed utility. This relationship is practically identical with that shown in a prevous chapter between the status of land tenure and plant depletion. The situation on the five general classes of ownership, based on the best information available from field surveys and published and unpublished records of the Department of Agriculture, is presented in table 58.

TABLE 58.—*The watershed situation on western range lands*

[In thousands of acres]

Ownership class	Principal water-yielding areas [1]			Areas of minor water yield					Total
	Con-tribut-ing little if any silt	Silting streams [2]		Silting streams [2]		Not silting streams [3]			
		Severe-ly eroded	Mate-rially eroded	Severe-ly eroded	Mate-rially eroded	Severe-ly eroded	Mate-rially eroded	Slight or no erosion	
National forests	61, 948	3, 357	13, 671	2, 212	1, 131	130	1, 529	3, 976	87, 954
Indian lands	5, 335	3, 572	3, 157	16, 128	7, 081	2, 540	9, 644	934	48, 391
Public domain, etc.[4]	4, 551	6, 525	3, 900	35, 867	20, 670	30, 560	46, 825	3, 107	152, 005
State, county, municipal	5, 527	2, 107	2, 736	20, 690	14, 581	5, 208	10, 248	4, 419	65, 516
Private	45, 617	7, 811	12, 937	96, 155	77, 682	36, 823	56, 514	42, 008	375, 547
Subtotal	--------	23, 372	36, 401	171, 052	121, 145	75, 261	124, 760		
Total	122, 978	59,773		292,197		200,021		54, 444	729, 413

[1] Range portion of watershed area furnishing 85 percent of water of major streams.
[2] Area contributing an appreciable amount of silt to streams.
[3] Area eroding, more or less, but not contributing appreciably to silting of streams.
[4] Includes grazing districts, public domain, and other Federal.

Management of the large acreage of privately owned range lands aimed primarily at the maximum utilization of forage has little regard, except in a few notable cases, for sustained production and for the watershed values on which nongrazing interests depend. The production of maximum numbers of steers and lambs is dominant throughout and water yield and erosion control only secondary, if considered at all. The average depletion in grazing value of about 51 percent on private lands indicates, at least in part, why 145 million acres of the private land area is severely eroded and 160 million acres is materially eroded; also why approximately 195 million acres is contributing appreciably to the silting of streams. These conditions indicate the seriousness of the watershed situation on private lands.

Unregulated and highly competitive grazing on public domain, part of which is now being placed under administration as grazing districts, has resulted in practically universal depletion both of the usable forage and the watershed values of these lands. Some other Federal reservations are leased without regard for conservation of the plant cover. Accordingly, there can be little surprise in the fact that approximately 98 percent of these lands as a group is eroding more or less seriously and about 67 million acres are contributing

appreciable quantities of silt to major streams, even though a large part occurs in the Great Basin, which does not drain into major streams.

Unregulated grazing in past years on most Indian lands has had the same effect. The extreme situation on the Navajo Reservation and several smaller reservations on the Rio Grande watershed in the Southwest accounts, in large part, for the high percentage of severely eroding area.

Rental and leasing of most State-owned grazing lands to private individuals have included no administrative supervision of the grazing, and this has meant that no attention whatsoever has been paid the preservation of watershed values, except as dictated by the self-interest of the lessee in preservation of the cover for range use.

Range lands on the national forests, where land use has been under administration with a watershed-protection objective, present a vastly different picture. This is also true of some municipally owned land, representing the water supplies of cities that do not depend on sources within the national forests. In these cases the general land-management policies have been influenced largely by public welfare. The watershed value of grazing land has been recognized and coordinated with grazing and other uses. The result has been that deterioration of the plant cover from overgrazing and fire has been greatly reduced, efforts have been made to restore the cover where depleted, and the yield of usable water and the soil conditions in general are superior to those under any other land tenure. Misused grazing land which has come under the administration of the Forest Service from time to time has for the most part been rehabilitated or started that way, instead of exploited further, with the result that the present range cover on the national forests is on an average depleted no more than 30 percent and only about 6.7 million acres are still eroding severely. These favorable results, no less than the dire results depicted on unmanaged lands, dispel any doubt that the same correlation which exists between ownership and depletion exists also between ownership and destruction of watershed resources, and for the same reason.

The Economic and Social Consequence of Accelerated Run-Off and Erosion

The immediate effects of accelerated run-off and erosion from unmanaged range lands are very serious, but they are only one chapter in the whole story. The economic and social outlook for the entire western United States is being threatened by the consequences of these combined destructive agencies. If this seems too bold an assertion, it is only necessary to turn to other countries and other times to find ample substantiation. Semple (*124*), supported by such other eminent authorities as Sir Napier Shaw and J. Hann, has ascribed the decline and fall of ancient civilizations to misuse of land and the resulting erosion which cut away the productive top soil of hills and fields, leaving in its place barren subsoil or sterile deposits of sand and rock. Homes and lives were, under such circumstances, destroyed by floods, famine followed devastation of agricultural land or loss of irrigation water and improvements, and the inhabitants of established communities were turned into roving

tribes because they could no longer sustain themselves at home. Syria, Palestine, and other Mediterranean countries were the chief sufferers because of climatic and physiographic features. China, as another example, still suffers greatly at irregular but frequent intervals from inundations that take a terrific toll in the great Yellow River Valley and similar areas. The disconcerting history of the water and watershed resources of old-world countries typifies what is now happening on a limited scale in the western United States and what will happen on a far greater scale if the natural resources upon which civilization is fundamentally built are not conserved.

Forage and water produced from the virgin range land were two of the most important resources which enabled the pioneers to build up the present civilization of the West as a monument to the hardships which they endured. The natural vegetation of the range furnished a source of feed upon which a great livestock industry was established. The run-off from the grass-covered hills and mountains contributed much of the water that made the settlement of cities and development of intensive farming and industry possible. Storage and diversion dams, ditches, and canals for irrigation projects were planned and built. Municipal water systems with dams and pipe lines brought water from mountain springs and streams to urban homes. Dams, turbines, and electric transmission lines harnessed water power and conveyed it to where it could be put to its greatest use.

With these industrial and agricultural developments, the population increased rapidly toward stabilization and a general atmosphere of security prevailed. Civilization had come and appeared permanent. But within a short time the first indications of impending disaster appeared in the realization of a few men and organizations that range depletion was occurring and would soon be reflected in reduced carrying capacity, loss of soil fertility, then loss of the soil itself, accompanied by devastating floods and unstable stream flow. These first indications were not particularly striking or evident and it has only been within the last years that general concern has been expressed. The permanency of these industrial and agricultural undertakings, whether it is realized or not, is dependent on the restoration and maintenance of as nearly virgin watershed conditions as possible within the catchment basins. If these virgin conditions can be improved upon, so much the better. For the most part, the point is now no longer argued that widespread deterioration of range lands is resulting in destruction of the soil cover. And the realization is growing that this soil cover has taken geological ages to produce and when once gone cannot be reproduced by any man-made process.

SOIL FERTILITY DESTROYED

Long before the topsoil is completely removed, harmful changes are wrought in its fertility and productivity, especially in the organic content of soil which is so essential to the absorptive and water-holding processes and the nitrogen content which is a prime requisite of plant growth.

The value of nitrogen and organic material in determining the quantity and quality of plant growth produced on a given soil has been amply demonstrated in agricultural practice. Their reapplication to soils already robbed of them by erosion and leaching resulted in a greater than 4-fold average annual increase in vegetation, over a period of 9 years, in recent tests in Utah (*137*). Of vast importance in range-forage production, they are the first elements of the soil to be lost through erosion.

In Idaho, in a survey of the Boise River watershed, soil samples taken from moderately depleted ranges, where erosion was barely under way, contained only 77 percent as much nitrogen and organic matter as soil from the virgin range; and soils from heavily depleted ranges already badly eroded contained only 61 percent as much nitrogen and 55 percent as much organic matter. In Utah, studies showed surface soils from an overgrazed, eroded area contained an average of 31 percent less nitrogen and 38 percent less organic matter than soils from the adjacent protected Salt Lake City watershed. When wheat was grown on both eroded and noneroded soils, but otherwise under exactly the same conditions—5.5 pounds of dry plant material was produced on a unit tract of eroded soil and 12.1 pounds on noneroded soil. Nitrogen and organic matter in surface soil from lightly, moderately, and heavily eroded areas in Davis County, Utah, were on the average 51 and 60 percent, 61 and 70 percent, and 75 and 84 percent deficient, respectively, as compared with noneroded soil.

When the surface soil and its litter and humus layers are partially destroyed, restoration of the range cover through the process of plant succession is exceedingly slow; since each stage in the succession must have increasingly better soil conditions until at last the climax range cover is attained. This slow process of soil building through plant development is, however, not hopeless except in severe cases of gullying and stripping where only geologic time can bring about reclamation. Examples of the slow progress of rehabilitation can be seen on certain areas on the national forests, which were badly eroded at the time the forests were created and even after more than 20 years of protection are still far from regaining the grazing capacity of the virgin range. One of the main reasons for this lag in productivity is deficient soil fertility.

IRRIGATION WATER SUPPLY AND IMPROVEMENTS THREATENED

Agricultural development of the West has been based largely on the cultivation of the semiarid, fertile, and arable lowlands supplied by life-giving streams from the more humid mountain areas (fig. 71). Any modification of rate and quantity of run-off upon which agricultural development is based is reflected in crop production, and as agriculture is built for the most part upon the best possible stream flow from the virgin watershed, the changes which have taken place are inevitably for the worse. If little water from melting snows is absorbed, extremely high peak flows result in the spring, at a season when irrigation is not needed. Indispensable irrigation water is poured out onto the waste lands or into the sea and lost. If the run-off from summer storms rages forth from the canyons as floods, farms

and communities, which by force of circumstances are located in floodable areas, will be devastated.

In other words, irrigated farming is based on usable run-off and if adequate reservoir capacity is not available, requires naturally controlled stream flow to sustain it properly. Natural flow of streams, however, by no means furnishes sufficient water to make all the fertile

FIGURE 71.—PLANT COVER ON MOUNTAIN SLOPES VITAL TO LOWLAND AGRICULTURE AND INDUSTRY

Lowland valleys such as shown in this aerial view of a section of Davis County, Utah, rely on a constant and usable supply of irrigation and domestic water from the more humid, steep mountain watersheds. To obtain this supply of water and at the same time avert the danger of floods, the plant cover of the watersheds must not be depleted. Where vegetation is destroyed, as on the headwaters of the center canyon here shown, floods and mud-rock flows will wreak great havoc in the agricultural lands below. That undepleted plant cover will furnish the desired protection to the lowlands is shown by the fact that no floods have come from the canyon to the right, where the cover has been maintained.

desert land blossom into productivity. Frequent water shortages occur in all Western States. Efforts are being made to overcome these shortages as rapidly as possible by building storage facilities where suitable reservoir sites are available to catch and hold surplus stream flow when it is not needed and release it when the parching fields require more than would otherwise be provided. The very considerable regulation of stream flow brought about by these improvements has been the means of stimulating agricultural development in many sections where it would have been impossible otherwise. Diver-

sion ditches and canals to conduct the water from rivers and streams help complete the reclamation undertaken.

These irrigation structures of one kind or another in the range-land States made possible the production of crops valued at nearly $900,000,000 (*159*) in the single year of 1929. The maintenance of the tremendous investment (table 59) in these works at maximum efficiency is a paramount consideration. A greater share of the stream flow upon which the irrigation depends is from the high mountain areas (fig. 72), many of which have been under national-forest administration for 30 years, thus insuring a measure of protection to the natural stream flow. The resources of the intermediate and lower and in some localities the higher elevational zones, however, have not been under administration. These have suffered much depletion of their plant cover from overgrazing and fire. As a consequence both the permanent and intermittent streams issuing from them are silt laden.

TABLE 59.—*Acreage of irrigated land, together with value of land, buildings, and machinery, and the value of irrigation improvements for irrigated farms in Western range-land States* [1]

State	Irrigated area	Value of land, buildings, and machinery	Value of reservoirs and distribution systems
	Acres	*Dollars*	*Dollars*
1. Arizona	575, 590	157, 290, 710	73, 328, 197
2. California	4, 746, 632	2, 535, 075, 016	450, 967, 979
3. Colorado	3, 393, 619	414, 180, 910	87, 603, 240
4. Idaho	2, 181, 250	316, 649, 034	84, 500, 354
5. Kansas	71, 290	13, 095, 069	1, 685, 652
6. Montana	1, 594, 912	205, 027, 415	50, 319, 204
7. Nebraska	532, 617	91, 773, 733	21, 386, 319
8. Nevada	486, 648	63, 998, 051	15, 457, 931
9. New Mexico	527, 033	93, 160, 485	19, 834, 380
10. North Dakota	9, 392	1, 452, 335	1, 267, 314
11. Oklahoma	1, 573	1, 771, 383	160, 099
12. Oregon	898, 713	171, 919, 001	38, 754, 548
13. South Dakota	67, 107	11, 576, 300	4, 502, 117
14. Texas	798, 917	190, 141, 304	49, 022, 164
15. Utah	1, 324, 125	212, 258, 249	35, 669, 819
16. Washington	499, 283	208, 738, 027	40, 561, 895
17. Wyoming	1, 236, 155	129, 692, 056	35, 153, 187
Total	18, 944, 856	4, 817, 799, 078	1, 010, 174, 399

[1] From Fifteenth Census (*159*).

CRITICAL CONDITIONS IN THE SOUTHWEST

At the present time a most critical situation from the irrigation and maintenance of irrigation improvement standpoints exists in the Southwest. This is true for three broad reasons: First, because such large portions of the southwestern watersheds are in the zones which have been badly depleted by unrestricted grazing; second, because the prevailing soil types are very susceptible to erosion; and third, because so many storage dams and diversion works are needed, creating an immense capital investment in the irrigation enterprise. Two of the most active expressions of the situation are seen in the devastating floods which occur and the growth of silt deposits in reservoirs and other irrigation works.

In this region small floods frequently wipe out individual farms and homes, and larger floods that inundate and spread destruction over entire communities are comparatively frequent. The irrigation

district in the Palo Verde Valley (*148*) on the Colorado River in California is often menaced by floods, a single one in 1922 causing damage estimated at $1,000,000. To combat the flood threat this district had, up to 1931, spent $2,400,000 on flood-protection work. The

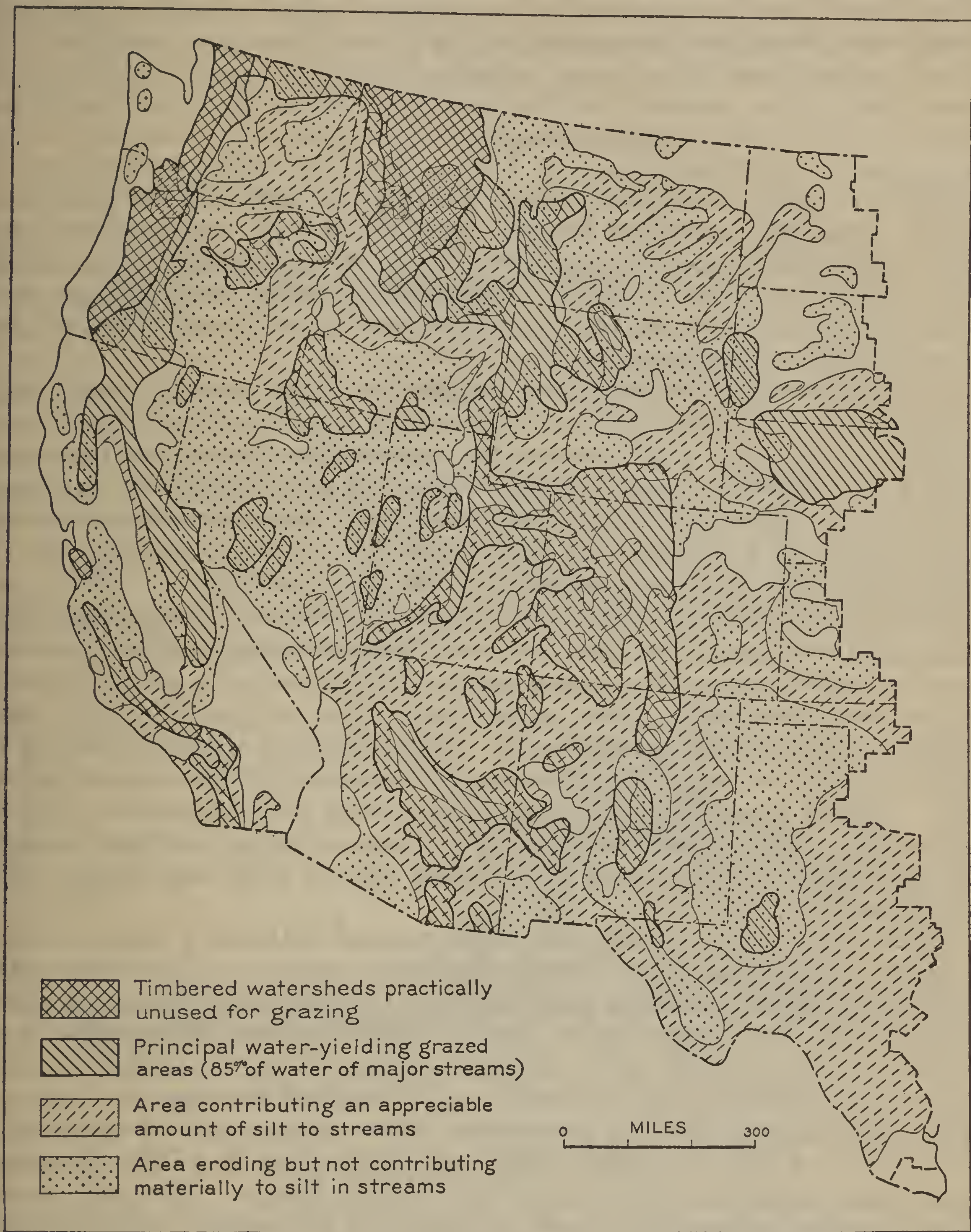

FIGURE 72.—IMPORTANT WATER-YIELDING AND SILT-PRODUCING AREAS.

Of the area yielding 85 percent of the flow of major streams, approximately 183,000,000 acres is grazed, 60,000,000 acres of which is contributing an appreciable amount of silt to streams. An additional 292,000,000 acres of range lands are also contributing appreciable quantities of silt to major streams. This means that the watershed utility is being impaired and that river beds, storage reservoirs, ditches, and canals are filling and clogging until their efficiency is seriously threatened.

lower Rio Grande Valley (*151*) in Texas and Mexico suffers also from floods at more or less frequent intervals. One occurring in 1932 practically wiped out flood-protection improvements costing approximately $5,000,000 and caused damage to other property estimated at $1,000,000 on the American side of the river alone.

The life of several storage reservoirs in the Southwest is being threatened by silt deposits which result from accelerated erosion in their catchment basins. Such rivers as the Colorado normally transported considerable silt in suspension, but denudation of the virgin range cover has aggravated the problem tremendously. In New Mexico the McMillan Reservoir on the Pecos River has been so completely silted that the dam is valuable only for diversion. Also in New Mexico the capacity of the Elephant Butte Reservoir is being reduced at the rate of approximately 20,000 acre-feet annually (*73*). The small Austin Reservoir in Texas, with an original capacity of 32,029 acre-feet, was filled almost completely with silt in 13 years (*140*). The new Boulder Dam is threatened with silting also, and on the basis of recent measurements (*54*) it is estimated it will fill with eroded material in about 220 years; its effective life from the water-storage standpoint will pass much sooner, if the silt load of the Colorado River is not reduced.

Deposition of silt in irrigation canals that must carry a steady and adequate flow of water to insure success of crops is a major problem in some localities. For instance, in the highly developed Imperial Valley of California, where crops valued at nearly $25,000,000 were produced in 1929 (*159*) alone, the estimated average annual cost of silt disposal and control was $1,330,000, the average annual cost to individual farmers being estimated at $2 per acre (*54*).

Silting of canals and reservoirs means not only the loss of the construction investment, but also the developments in agriculture, power, etc., dependent upon the stored water. If a new site can be found and a new dam built, their added cost must be saddled upon the already overburdened water users. Rebuilding of silted reservoirs is not, therefore, a feasible or reasonable solution of the erosion problem. Where no other site is available, even this expensive cure is impossible. The dependent industries must collapse and the dependent population be uprooted and thrust out to seek new homes and livelihoods.

What accelerated erosion and rapid run-off following deterioration of plant cover caused by overgrazing may mean to community welfare is well illustrated by a small area on the San Juan River between Shiprock, N. Mex., and Bluff, Utah. Shortly after this region was settled, in about 1880, the excellent grazing lands available in the valley and surrounding mountains were stocked heavily with sheep, cattle, and horses, and the prosperous little community of Bluff was built up. At one time this town was reputed to have the greatest per-capita wealth of any town in the United States. By 1935, however, drastic changes had been wrought in the range cover and in the dependent community. The density of range vegetation had decreased from an average of 58 percent to less than 4 percent; one-half of the agricultural lands had been eroded away; damage from floods and erosion estimated at approximately $780,000 had been caused; 10 lives had been taken by flood waters; property was tax-delinquent; and the village population had declined from 600 to 50 people. This community literally signed its own death warrant by disregarding the consequences of range destruction.

The great gullies and sterile plains now in evidence on the Navajo Indian Reservation (*189*) are further indications of the ravages of

water on depleted range lands in the Southwest. The very existence of these Indians, scanty as it is, is threatened by accelerated and unrestrained erosion. Water holes are drying up and floods are common. Against the processes of erosion of his own making, the red man's last stand is futile. Fortunately, in the last few years the plight of this tribe has been recognized, and Government agencies are endeavoring to restore the cover of vegetation and halt soil wastage.

THE COST OF WASTE WATER

The upper Colorado River Basin furnishes more than 85 percent of the total flow of the Colorado River system. Nearly a billion dollars of existing and potential developments are dependent on the flow of this river and its tributaries. Without question, where capital investments of such magnitude depend to a large degree upon the flow of one river, its watershed must be carefully managed. If the direct value of a billion-dollar investment is depreciated 20, or even only 10, percent by avoidable lack of control of stream flow, the financial loss is as inexcusable as it is appalling. The indirect social and economic losses which cannot be measured in terms of dollars would be even more striking, however, if they were fully understood, since active soil erosion and floods attack the welfare not only of the irrigationist near the headwaters of the stream, but also the citizen of Los Angeles, who looks to the Colorado River to produce a portion of his municipal water supply.

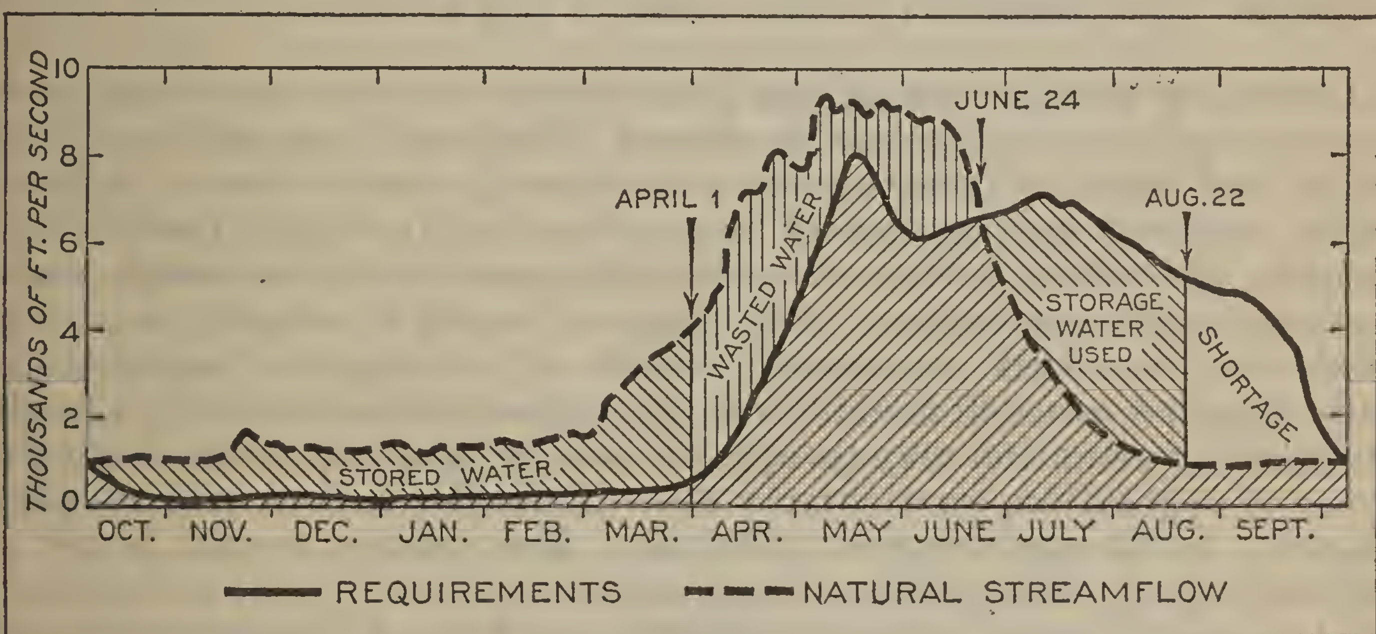

FIGURE 73.—RELATION OF AVERAGE ANNUAL FLOW OF BOISE RIVER TO ACTUAL WATER REQUIREMENTS.

Under present average watershed and stream-flow conditions, and with present storage facilities on the Boise River, water is wasted (on the average) after April 1, when dams are filled to capacity. By June 24 stored water must be used, and this use lasts until August 22, after which a shortage occurs which results in an average annual loss in gross income estimated at $1,914,800. Additional storage is economically impracticable. If spring run-off were to be delayed by careful management of the watershed cover, less of the peak flow would be wasted and more water would be available in the late summer for maturing crops.

Where the demand for usable irrigation water far exceeds the supply, as, for example, in southern Idaho, the need for careful management of watershed resources can be vividly illustrated. Under such circumstances it is absolutely necessary that streams produce a maximum flow in the most usable form. Figure 73 pictures normal flow, the average actual flow as developed from stored water, and the average annual water shortage which arises on the Boise River. The

average annual waste of water down this river, owing to lack of sufficient storage facilities, is approximately 448,000 acre-feet. On June 24, on the average, the natural flow of the river drops below requirements, and it is necessary to supply the deficiency from stored water. The reservoirs which thus supplement the flow are drained, on the average, by August 22. To provide for maximum-crop production, however, water should be available through September in a quantity of 272,632 acre-feet over and above the average flow during this late-summer and early-autumn period.

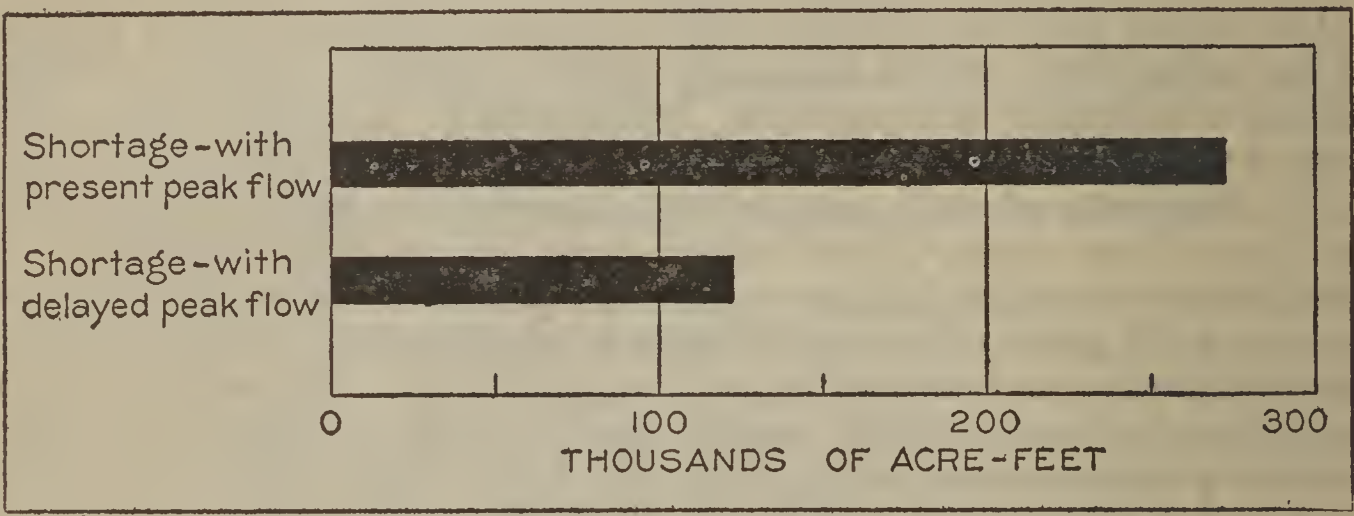

FIGURE 74.—PRESENT AVERAGE ACTUAL WATER SHORTAGE, CONTRASTED WITH SHORTAGE IF PEAK FLOW COULD BE DELAYED 10 DAYS.

If it were possible to so manage the plant cover of watershed lands as to delay peak flow of the Boise River 10 days—and indications are that some such delay might be accomplished—the average annual shortage of water could be reduced 55 percent, making additional water available at the season when it is badly needed.

Obviously two courses appear to be open to correct this situation—more storage or delayed spring run-off. Surveys have indicated that additional storage facilities are economically unpractical. Accordingly, delayed spring run-off appears to be the only feasible approach; and while it cannot be definitely stated that intensive management will consummate this purpose on this already comparatively well-handled watershed, studies of absorption, penetration, and retarded run-off made thus far indicate that at least a more satisfactory situation may be approached by properly controlling the cover of vegetation, particularly that of the herbaceous and shrubby plants. A 10-day delay in the peak flow, which would bring it approximately at the peak of requirements, would result in an average annual shortage of only 123,000 acre-feet of water, instead of the actual shortage of some 273,000 acre-feet (fig. 74). This average increase in available water, coming at a season when irrigation is so urgently needed, would mean a material decrease in the $1,914,800 average annual loss in gross income that water shortage now causes. The general theory of this discussion pertains to many watersheds of the West, of which the Boise River is only one example upon which data are available.

The proper management of the range cover to delay run-off from a specific watershed is not confined within the boundaries of the watershed itself. Lowland areas of depleted plant cover entirely outside the watershed may influence materially the yield of usable water from a mountain watershed by contributing to early spring dust storms. At the time that most serious dust storms originate, the most important western watersheds are covered with a winter's

accumulation of snow which should melt slowly to insure properly regulated stream flow. However, when dust from depleted lowland areas is deposited in the mountains, the snow cover melts perceptibly faster. The dust cover on the snow absorbs heat from the sun rays to a far greater degree than the snow surface itself. The effect is that of placing a warm blanket over the snow surface, and more rapid run-off is the outcome. During the spring of 1934 this general phenomenon was observed throughout the intermountain region. It forcibly illustrated the conclusion that watershed protection is not confined to watershed boundaries but is a regional problem.

COSTLY FLOODS

The importance of watershed resources is probably recognized more fully in California and Utah than elsewhere in the West, largely as the result of a series of catastrophes. In California the floods in and around Los Angeles have brought home the realization that many other communities have thus far missed—that denudation of a watershed, regardless of cause, is a serious menace to life and property. In the previously mentioned La Crescenta flood 30 lives were lost, 483 homes destroyed, and a total damage caused that was estimated at $5,000,000. At present in this same locality 380,000 persons and property valued at $300,000,000 are still directly subject to the ravages of floods if the local watersheds are devegetated (*45*).

In Utah, devastating floods and mud-rock flows issuing from misused watersheds along the Wasatch Mountain front have made the entire State conscious of the consequences of range depletion. During a 10-year period prior to 1934 damages conservatively estimated at slightly more than $1,000,000 have been caused by such floods in the small, intensively farmed section between Ogden and Salt Lake City.

The communities Centerville and Bountiful, adjacent to where these floods occurred, recognized the value of a protected watershed some years ago and gained control from private owners of the area directly influencing them. Under their protective administration the plant cover has been maintained, no floods have been experienced, and a healthy feeling of security foreign to their less farsighted neighbors is well established.

These examples might be multiplied many times over. As previously discussed, the flood situation is not limited to one locality. Costly floods, in both life and property, occur every year in nearly all parts of the range country as a consequence of depletion of the protective vegetation.

MUNICIPAL WATERSHEDS

The necessity for the protection of watersheds furnishing water for municipal use has been recognized almost universally where the source of supply is relatively near to the point of consumption. As a rule, the watersheds yielding water for cities of any size, such as Salt Lake City and Denver, are either under municipal regulation or are included in the national forests. The role of vegetation is recognized, and strict supervision of all activities on the watersheds is enforced.

Cities drawing water from rivers and streams whose headwaters are remote to them should be actively interested in seeing to it that their watersheds are under the jurisdiction of a public agency interested in watershed protection. Civic growth and development are limited by the amount of usable water available. It should be realized that the building of a new factory or the exploitation of a new subdivision may depend upon whether or not accelerated and uncontrolled run-off and erosion are occurring on a watershed some few hundred miles distant. For example, Los Angeles is vitally concerned with the life of the Boulder Dam and the acceleration of erosion and run-off on the Colorado River above it.

WATER POWER DEPENDS ON CONTINUOUS STREAM FLOW

Municipalities and industrial enterprises should be concerned with the eventualities which face their supply of electricity generated by water power. The water power resources of the West are one of its greatest heritages, and it is not intimated that power shortages could arise, providing capital is available for their development. But uncontrolled run-off and silting of dams may not only jeopardize undepreciated investments but actually limit industrial and domestic expansion because of the excessive costs of producing power on new sites in more remote localities.

RECREATION AND WILDLIFE RESOURCES IMPERILED

To the millions of sportsmen, recreationists, and wildlife conservationists through the entire United States, the effect of accelerated, heavily silt-laden run-off on the fish resources and recreational value of mountain streams is of vital interest. Many recreationists have returned to what they remembered as a permanent camping and fishing paradise, only to find camp grounds eroded away, stream banks freshly cut and denuded of vegetation, favorite fishing holes filled with silt, moss-covered rocks of the stream-bed scoured clean by silt and gravel, and fish that once tested their skill, gone. Gone not because they had been hooked, but because the disturbance of their native habitat and food supply had made existence impossible, or because they had been washed from their holes and sheltered havens by floods and mud flows. Game and fighting fish demand fairly natural or virgin conditions of habitat and channeled and scoured streambeds will inevitably cause migration or death.

The consequences of accelerated erosion on streams in and upon which the fish and campgrounds are destroyed are broad. The rural community or business enterprise suffers a declining tourist trade, a source of income upon which more and more persons have lately come to depend; and the recreationist, who is rapidly becoming more prominent both in numbers and in his dependence on outdoor enjoyments is deprived of diversions essential to peace of mind, health, and happiness.

"BLACK BLIZZARDS" OF THE PLAINS SPREAD DESTRUCTION

Dust storms caused by the action of wind on denuded soil surfaces have already been mentioned. They have produced serious

consequences during the past few years. Beginning in 1932, and again in 1934 and 1935, great clouds of dust have rolled eastward from the Great Plains owing to a combination of drought, wind, and devegetation which resulted from the attempt to cultivate true grazing land. Abandoned farms now stand as ghostly evidence to man's lack of regard for nature's balance and the vicissitudes of climate. The physical and mental suffering involved have been appalling. Homes have been deserted and a despondent yet virile farm population thrust out to experience the hardships of seeking new homes in a country lacking more unappropriated arable land. In general, the dust storms of the past and the potential hazards of future ones have made a considerable section of the Great Plains a less desirable place in which to live for both the urban and rural dweller. Business enterprises are insecure, farming hazardous and personal health endangered.

Dust storms have arisen also from the range lands in the Great Basin, Columbia River Plateau, and southwestern regions, and although the local area affected has been much smaller, their consequences are similar to the storms originating in the Great Plains.

CONTRASTING WATERSHED AND GRAZING VALUES

Although grazing is often considered the outstanding value of range lands, watershed protection may be of even greater importance on over half of the total range area. The grazing value of these watershed lands seldom exceeds $3 per acre and is often less in their present denuded condition. The actual value for watershed protection has never definitely been measured. Investments of over 5.8 billion dollars in irrigated land and improvements compare with about 4.1 billion invested in range livestock and private range lands and facilities used in their production. Of the 475 million acres of range land making up either the important water-yielding or silt-contributing areas of major stream basins every acre supports an average investment of $12.27 in irrigation works, irrigated land, and facilities. In addition these areas support millions of dollars invested in power facilities which furnish electric light and power for cities and industry; a large part are on drainage areas which supply water to thousands of communities.

The Boise River watershed in Idaho supports a dependent agricultural investment in the valley of about 53 million dollars equal to $32 for every watershed acre. The watershed of the Roosevelt Reservoir, the storage basin of the Salt River project in Arizona, supports an investment of $67 and a yearly production value, as of 1928, in agricultural crops and power of $9 for every watershed acre.

Silt accumulations in many important reservoirs of the West, primarily the result of accelerated erosion caused by range depletion, are threatening the permanency of the communities which such improvements have made possible. In the relatively short period of 17 years, 13 percent of the capacity of the Elephant Butte Reservoir in New Mexico, for example, has been completely silted. The Rio Grande channel, near Albuquerque, has become so choked that it will cost over 10 million dollars to provide flood protection and drainage works. These examples could be supplemented by many more, some of which have already been given.

The extreme flood hazard of the West, under present conditions of impaired watersheds, results annually in unjustified loss of life and millions of dollars in property damage. The floods from depleted watersheds of Davis County, Utah, wrought havoc in the valley communities equivalent to $75 per acre for the entire watershed; if this damage were prorated only on the denuded areas from which the flood waters came, the losses would aggregate $1,245 per watershed acre. Had protective cover been there such damage would not have resulted. High values have also been placed upon the steep mountain brush-covered watershed lands of Los Angeles County, Calif., where the value of services in water delivery and flood protection have been estimated at $300 per acre. Such destruction as emanated in the La Crescenta flood on New Year's Day, 1934, from an extremely small burned watershed area, clearly indicates the great importance of maintaining the protective value of the vegetation on these steep mountain watersheds unimpaired.

Protection of these critical irrigation and other community values, dependent on effective watershed maintenance, means more to the West as a whole than the ranches and livestock dependent on the watersheds for grazing or the value of the forage which these watersheds produce. If it should become necessary to choose between exclusion of livestock for watershed protection and continuation of grazing, unquestionably the only practical course would be to eliminate grazing. However, if proper coordination of grazing and watershed protection were provided, elimination of grazing from watershed lands, except on relatively small areas, would not be necessary. Many of the irrigated ranches owe their economic soundness to the fact that range forage produced on the watershed lands can be utilized by livestock fed part of the year on the ranch. The outlying communities on these watershed lands also serve a useful economic and social purpose. Continued grazing of these watersheds under proper regulation is therefore desirable. Responsibility for maintaining favorable watershed conditions on the several hundred million acres of range lands, insofar as grazing use is concerned, accordingly rests both with the livestock industry and the public.

The Way Out—Restoration

Fortunately the destruction of the watershed resources of the virgin range has not as a whole proceeded to the point where the situation is hopeless. Certain bright spots are still scattered over the entire West, and with these and the policies which have been applied to them as a nucleus, a way out of the present dilemma is indicated.

Municipal watersheds which have been protected, certain privately owned lands upon which productivity has been maintained, and national forests which have been managed with watershed conservation as a major consideration, make up the favorable side of the present picture. For the most part accelerated erosion and floods offer no problem on these areas because of the suitable plant cover which has been sustained or restored on them since they came under their present ownership or control. On the national forests, as an illustration, one of the most important responsibilities associated with the administration of range lands has been their protection and management as watersheds. This duty has been recognized since

the creation of the forests, and fortunately for the sustained development of the West, many important water-yielding areas are included within their boundaries. At the time the Forest Service undertook administration of the national forests, the cover on many watersheds had been so severely depleted that erosion was rampant and floods were common. Now, under a system of land management that has watershed conservation as a basic principle, most of these eroding areas have been improved and many have been rehabilitated completely.

Reference has already been made to the Manti National Forest in Utah, where it has been said that at one time the number of bands of sheep could be counted by the dust clouds which they raised. Inevitably, these depleted ranges became eroded severely and floods occurred. The settlement at Manti and others situated on the valley floor experienced their first floods in 1888 after more than 30 years of security. These first floods were followed by others more devastating, until the effects of reduced stocking and regulated grazing following the creation of the national forests began to be reflected in a restored plant cover. Thus through protection and rehabilitation erosion was halted, run-off was regulated as satisfactorily as possible under natural conditions, and floods, since 1910, have been unknown.

The history of Forest Service administration of grazing land is replete with such examples. Owing to the very badly depleted condition of the ranges prior to the creation of the forests and the economic demands upon the ranges since that time, erosion has not been halted completely in every case, but enough has been done to make it evident that control by vegetation is possible and feasible except where erosion is extreme.

Although climate with its vicissitudes of drought, torrential storms, and excessive precipitation; topography with varying degrees of slope; and soils with contrasting susceptibility to erosion, are important factors in the stability of the watershed resources, the plant cover of the range has been shown by conclusive research to be the key to the situation and it is the only one that man can manipulate. Unwise use and lack of management on a large share of the range lands have brought about the present state of depletion and devastation and this misfortune must be corrected and improved. Rehabilitation and continued maintenance of a plant cover is the method whereby erosion scars can be healed, silt load of streams reduced, and unregulated and flood-producing run-off controlled in a manner that will yield the maximum quantity of usable water.

The western United States stands today at the crossroads and must choose between controlled management of its vast area of unregulated grazing land or continued exploitation and eventual devastation. The latter course leads to a China or Syria, with accessible range and forest land almost totally devastated and inundating floods of common occurrence. The other leads to conditions similar to those in many nations of Central Europe, where efficient land management policies are practiced to conserve and protect the watersheds. Without doubt the efficacy and desirability of the road to proper and conservative management has been demonstrated by the history and present status of these contrasting nations. Cannot America profit by this experience?

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